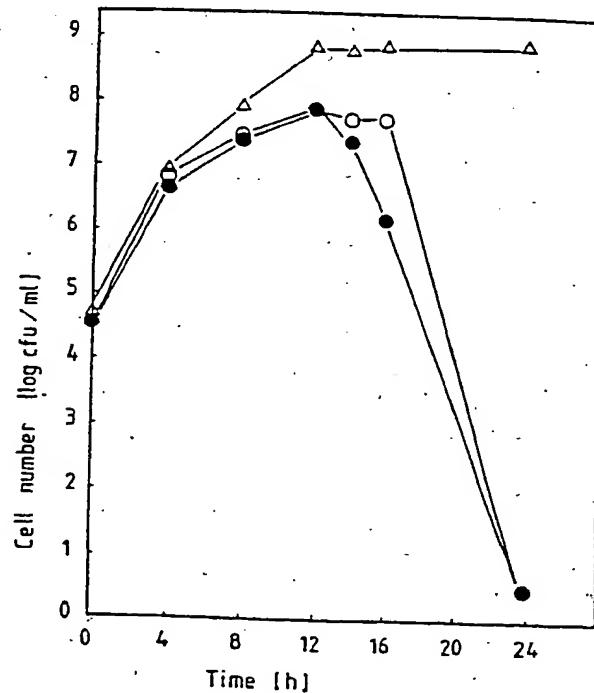




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(54) Title: PRODUCTS FOR INHIBITING THE ADHESION, GROWTH AND/OR SURVIVAL OF PATHOGENS



(57) Abstract

Products for inhibiting the adhesion, growth and/or survival of pathogens are disclosed. The products are Lactobacill metabolites, including high molecular weight proteinaceous compounds, which inhibit the adhesion, growth and/or survival of pathogens, such as *Escherichia coli*, *Clostridium*, *Salmonella*, *Campylobacter* and *Streptococcus* strains.

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PRODUCTS FOR INHIBITING THE ADHESION, GROWTH AND/OR
SURVIVAL OF PATHOGENS

5 The present invention concerns products for inhibiting the adhesion of pathogens to intestinal epithelial mucosa, or for inhibiting the growth and/or survival of pathogens in animals including humans.

10 The invention also concerns a method for producing said products and preparations containing the products. Furthermore, the invention concerns preparations containing the products or viable strains of certain Lactobacillus as well as a method of treating animals with the claimed products.

15 The products are Lactobacillus metabolites, including high molecular weight proteinaceous compounds, which inhibit the adhesion, growth and/or survival of pathogens, such as *Escherichia coli*, *Clostridium*, *Salmonella*, *Campylobacter* and *Streptococcus* strains.

20 The role of Lactobacillus within the gastrointestinal tract has been extensively investigated and reviewed (e.g. Sandine et al, 1972; Speck, 1976; Sandine, 1979; Alm, 1980; Pollmann et al, 1980; Shahani and Ayebo, 1980; Fernandes et al, 1987) and a number of beneficial roles have been proposed (see Table 1).

Table 1

25 Summary of the reported beneficial effects of lactobacillus in the gastrointestinal tract. Numbers in parenthesis refer to examples of studies for each area.

30 Establishment and stabilization of the gut microflora (1)
Protection against pathogen colonization (2)
Reduces bacterial diarrhea and subsequent mortality (3)
Production of bacteriocins/antimicrobial compounds (4)
Increased weight gain for a range of animal hosts (5, 6)
Stimulation of the immune system (7)
35 Decreased incidence of tumours (8)
Decreased risk for colon cancer (9)

(cont.)

(cont. Table 1)

Assimilation of cholesterol (10)

Reduction of serum cholesterol (11)

Deconjugation of bile acids (12)

5 Improved gastrointestinal motility in the elderly (13)

Improved egg production and quality in hens (14)

Improved nutritional status of food (15)

Improved tolerance of lactose (16)

Metabolism of some drugs (17)

10

1. Morotomi et al, 1975; 2. Muralidhara et al, 1977; 3.

Luckey, 1984; 4. Barefoot and Klaenhammer, 1983; 5.

Robinson and Thompson, 1952; 6. Lessard and Brisson, 1987;

7. Perdigon et al, 1987; 8. Goldin and Gorbach, 1980; 9.

15 Goldin et al, 1980; 10. Gunewald, 1982; 11. Gilliland et al, 1985; 12. Gilliland and Speck, 1977; 13. Alm et al, 1983; 14. Miles et al, 1981; 15. Gurr, 1987; 16. Kolars et al, 1984; 17. Pradham and Majumdar, 1986.

For all the studies presenting the beneficial role of 20 the entire normal microflora, there have been almost as many studies implicating lactobacilli as having the capacity to achieve similar beneficial effects. Clearly, the validity of such a situation raises doubt in the minds of many. Doubts have been strengthened by contradictory 25 non-conclusive results as to the beneficial effects of lactobacilli (e.g. as summarized by Tuschy, 1986).

Non-conclusive or not statistically significant results are often reported when attempts are made to confirm that lactobacilli improve the health of the host.

30 Inconsistencies in reports began at the turn of the century, when the works of Cohendy (1906a and b) and Belonovsky (1907) showing colonization of the intestine were not supported by other studies in which the administered strain could not be established (Luerssen and Kühn, 35 1908; Herter and Kendall, 1908; Distaso and Schiller, 1914; Hull and Rettger, 1914). This situation continues to occur today as many workers report a failure in persis-

tence of administered lactobacilli (e.g. Jonsson, 1986; Pedersen and Tannock, 1986) while others have succeeded in achieving implantation in the same host (Conway et al, manuscript). Contradictory results appear for all reported 5 beneficial effects. For example, Muralidhara et al (1977) reported a decrease in *E. coli* in lactobacilli dosed pigs while Pollmann et al (1980) showed no difference in *E. coli* levels between control and lactobacilli dosed piglets. These types of results are assumed to be comparable 10 without consideration that lactobacilli strains and conditions of the host may vary markedly.

It has been convincingly shown that lactobacilli are beneficial for the health of newborn babies (e.g. Yoshioka et al, 1983) as suggested for fowls (Fuller, 1973), and 15 that they reduce pathogenic coloform levels (e.g. Barrow et al, 1980). A common statement in the introduction of papers dealing with lactobacilli in the gastrointestinal tract is: Lactobacilli are known to regulate the intestinal microflora and influence the health and well 20 being of the host. This poorly defined statement is not entirely supported by published data. Within the adult alimentary tract, the clear definition of the role of indigenous lactobacilli has been clouded by the issue of whether ingested lactobacilli play a beneficial role, in 25 some cases without distinguishing that the lactobacilli used to produce fermented milk products may have entirely different characteristics from those colonizing the gastrointestinal tract. There is a very obvious trend that lactobacilli contribute significantly to the well being of 30 the host (reviews cited previously), however, this has often been reflected as trends rather than conclusive facts and reports often differ.

INDIGENOUS LACTOBACILLI OF THE GASTROINTESTINAL ECOSYSTEM Description of the Ecosystem

35 The gastrointestinal tract of man and most animals is a complex ecosystem in which a dynamic equilibrium exists between the microflora, the diet and the host (Savage,

1977). Contributions to the ecosystem from the host include the peristalsis and motility, the immune response, the mucosal surface and secretions. The microflora consists of extremely diverse bacterial species colonizing 5 both luminal contents and epithelia surfaces. Nisse (1916) was the first to propose that the intestinal microflora may yield protection against infection and Freter (1955, 1956) provided direct evidence that elimination of the flora rendered animals susceptible to pathogens. While it 10 has been shown by many that the normal microflora play a protection role (reviewed by Hentges, 1983), the specific contribution of the lactobacilli is more diffuse. In the new-born, lactobacilli constitute the major bacterial genus prior to the successive colonization by other 15 bacterial species from the environment and the mother (e.g. Bettelheim et al, 1974; Ducluzeau, 1983). Using conventional and gnotobiotic animals, Morotomi et al (1975) showed that lactobacilli control the population levels of bacteria in the stomach and small intestines of 20 rats (Morotomi et al, 1975). Robinson and Thompson (1952) reported that breast fed infants developed a stable microflora of about 99% *Lactobacillus bifidus* within 3 to 4 days and that these lactobacilli lowered the incidence of colic and digestive disturbances. The introduction of 25 cow's milk has been shown to decrease the numbers of *L. bifidus* and increase the numbers of *E. coli* by 1-2 and 2-3 log counts, respectively (Willis et al, 1973). Ingestion of solid food induces the rapid development of the complex microflora, of which *Lactobacillus* represents one of the 30 dominant groups.

The average levels of lactobacilli cultured from samples through the alimentary tract are shown in Table 2. While the data for humans reflects the luminal contents profile, numerous animal studies have demonstrated that 35 *Lactobacillus* colonized the squamous epithelia of a range of hosts including chickens (Fuller and Turvey, 1971), swine (Tannock and Smith, 1970) and rodents (Brownlee and

Moss, 1961). Permanent colonization of the human epithelium has not been examined to date, however, lactobacilli have been cultured from surgical samples from the mucosa of the jejunum (Plaut et al, 1967; Nelson and

5 Mata, 1970) and colon (Nelson and Mata, 1970; Edmiston et al, 1982). These studies, supported by the demonstration of in vitro adhesion to human ileal cells (Conway et al, 1987) and to fetal intestinal cells (Kleeman and Klaenhammer, 1982), is suggestive that colonization of the

10 healthy human mucosa may occur.

Table 2

Occurrence of lactobacilli in the gastrointestinal tract of man and pigs. Values expressed as log bacteria per ml or gram of contents and per 100 mm² epithelial surface.

15

	Host	Stomach		Ileum		Colon
		Surface	Contents	Surface	Contents	
	Man ^a	ND	0-4	ND	3-7	4-8
20	Rats ^b	3-4	ND	ND	ND	7-9
	Pigs ^c	7.9	8.9	6.9	8.3	9.6

a. Data compiled from Evaldson et al (1982)

b. Data compiled from Adams and Conway (1981)

25 c. Data compiled from Conway et al (manuscript in preparation)

ND corresponds to no available data

Stability

During development in the young, the normal microflora is rather unstable and the host therefore more susceptible to invasion by ingested pathogens. In contrast, the normal human adult microflora has been shown to be remarkably stable (reviewed by Hentges, 1983), although this may reflect difficulties of sampling and culturing, 30 because changes have only largely been observed for the easily recognized and cultured bacterial types (Tannock, 1983). Consequently, lactobacilli have been shown to be

sensitive to change, for example, lactobacilli are suppressed very rapidly in man when the subject is exposed to nervous-emotional stress effects, as provoked prior to cosmic flights (Lizko et al, 1984). Furthermore, piglets 5 when being weaned onto solid foods are extremely susceptible to bacterial induced diarrhea from *E. coli* K88 (e.g. Tziperi et al, 1984).

From numerous animal dietary studies, the lactobacilli emerge as indicators of dietary stress (reviewed 10 by Tannock, 1983). Mice fed a semisynthetic diet had fewer faecal lactobacilli than controls (Dubos and Schaedler, 1962) and rats fed a meat diet (Brownlee and Moss, 1961), a synthetic corn oil diet (Brockett and Tannock, 1981) or dietary additives (Adams, 1980; Adams and Conway, 1981) 15 had no lactobacilli remaining adhered to the squamous epithelium. In addition, rodents had fewer lactobacilli in the stomach and intestine after several days of starvation (Porter nad Rettger, 1940; Morishita and Miyaki, 1979), as well as no detectable surface associated lactobacilli 20 (Tannock and Savage, 1974; Conway et al, 1986). The role the diet can play on colonization by lactobacilli is further emphasised by the work of Lhuillery et al (1981). These workers showed that, while germ free mice fed either a commercial diet or a semi-synthetic diet were similarly 25 colonized with a *Lactobacillus* strain, the off-spring of the semi-synthetic diet fed animals lacked the strain during lactation. The off-spring from the mice receiving commercial diet were rapidly colonized.

REPORTED BENEFICIAL EFFECTS

30 The proposed beneficial effects range from direct bacterial interactions with pathogens to interactions with the host physiology and antitumour activities (Table 1). A general phenomenon throughout all roles is that the growth and most probably metabolites of lactobacilli exert an 35 effect within the gut ecosystem. This effect may directly or indirectly be beneficial. The antimicrobial, anti-cholesteremic and anticarcinogenic activities have been

recently reviewed (Fernandes et al, 1987), as has the enhanced bioavailability of nutrients and tolerance to lactose (Gurr, 1987). These can be broadly divided into antimicrobial, physiological and biochemical effects.

5 Antimicrobial activitets

It has been shown that dosage of lactobacilli significantly decreases numbers of *E. coli* in vivo in chickens (Fuller, 1978), pigs (Barrow et al, 1980) and humans (Lidbeck et al, 1987), to cite just a few examples. Such 10 an effect could lead to improved weight gain, improved egg production and quality, and decreased incidence of diarrhea and mortality but demonstration of such indirect effects has often been inconclusive. The lactobacilli have been shown in vitro to act directly on pathogens by inhibition of growth. This growth inhibition has been considered 15 the major antagonistic action of lactobacilli. This view may be too simplified and perhaps it is more appropriate to talk in terms of competitive colonization which includes growth and colonization inhibition.

20 Lactobacillus primary metabolites such as lactic and acetic acid and hydrogen peroxide have been shown to be inhibitory to the growth of pathogens (e.g. reviewed Klaenhammer, 1982). In addition, low molecular weight metabolites with antagonistic properties have been reported, 25 with some being active against specific strains (e.g. Barefoot and Klaenhammer, 1983; McCormick and Savage, 1983) while other workers report compounds with broad spectrum in vitro antagonistic activities (Goldin and Gorbach, 1987; Axelsson et al, 1987).

30 Ten Brink et al (1987) raised the issue that many reported antimicrobial compounds of lactobacilli are primary metabolites and proposed a new screening procedure. Using this method, two strains were shown to produce a protein-like antimicrobial compound active against a 35 limited number of Gram positive bacteria.

The concept of competitive inhibition implies that the lactobacilli may out-compete the pathogens by either occupying the binding sites on the epithelia or exhausting the nutrients. This concept has been used in *Neurospora* and

5 Rantala (1973) who implanted a mixture of non-pathogenic
bacteria in the chicken to prevent pathogens establishing
and Duval-Ifalh et al (1982) by introducing non-pathogenic
E. coli in babies to competitively exclude antibiotic
resistant E. coli. Pathogenic bacterial strains, e.g.
10 enteropathogenic E. coli, colonize the gastrointestinal
tract e.g. by adhering to the intestinal mucosa using
proteinaceous fimbrial appendages such as the K88, K99,
CFA/I, CFA/II, 987p and F41. Competition for the
epithelial cell surface has been shown in an in vitro
15 study in which E. coli cells were unable to adhere to
epithelial cells already colonized by Lactobacillus
acidophilus (Table 3).

Table 3

Adhesion of *E. coli* K88 and *L. acidophilus* to pig ileal

20 cells.

Bacteria	Pre-treatment*	Bacteria Adhering per ileal cell
L. acidophilus	-	165
E. coli	-	78
E. coli	+	0

* Ileal cells incubated with *L. acidophilus* prior to assay.

30 In Swedish Patent Application No. 8405587-0,
especially the new description filed on September 25,
1986, there is described a method of enhancing the
adhesion of e.g. *lactobacillus* and *Streptococcus* to the
gastrointestinal tract of experimental animals. It was
35 found that the specific binding of the organisms to
epithelial cells of the host organism is mediated by a
certain protein, the so called APP (adhesive promoting

protein). This method is thus concerned with the concept of outconcurring pathogens in the gastrointestinal tract by administering beneficial bacilli, which adhere to the epithelial mucosa and colonize the gut.

5 The present invention is concerned with the problem of gastrointestinal disturbances which are induced by, for example, antibiotic dosage or dietary alterations, resulting in pathogenic bacterial infections, for example, travellers diarrhea in humans, outbreaks of gastrointestinal infections in piglets.

One object of the invention is to provide products for inhibiting the adhesion of pathogens to gastrointestinal epithelium of humans and animals.

15 Another object of the invention is to provide products for inhibiting the growth of pathogens in animals including humans.

A further object is to provide products for inhibiting the survival of pathogens in animals including humans.

20 Yet another object of the invention is to provide a method of producing products for inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or for inhibiting the growth and/or survival of pathogens in animals including humans.

25 A further object of the invention is to provide preparations containing, as an active ingredient, products for inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or inhibiting the growth and/or survival of pathogens in animals including humans.

30 Another object of the invention is to provide preparations containing viable strains of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to which the preparations will be administered.

A further object of the invention is to provide 35 methods of inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or inhibiting the growth and/or survival of pathogens in animals including humans.

10

We have recently demonstrated a protein-like metabolite with a molecular weight greater than 8,000 and that is active against a series of *E. coli* pig pathogens. These protein-like compounds may fall into the category of 5 bacteriocins as described by Tagg (1976), who defined them as plasmid encoded, protein molecules which have a narrow bacteriocidal range and function by attachment to specific cell receptors.

In a separate study, preliminary results have shown 10 that the adhesion of an *E. coli* K88 strain to pig intestinal mucosa was inhibited by the high molecular weight metabolites of lactobacilli isolated from the pig but not of lactobacilli from the mouse digestive tract (Table 4). Subsequent studies suggest that this was not the growth 15 inhibitory compound and the mechanism of inhibition of adhesion is being investigated. *Lactobacillus* metabolites may inhibit pathogen colonization of the mucosal surface which is a prerequisite for pathogenicity for many strains. Consequently, factors in addition to growth 20 inhibitory activities should also be considered.

Table 4

Adhesion of *E. coli* K88 to pig mucus containing the receptor in the presence of high molecular metabolites of lactobacilli strains from the digestive tract of mouse or 25 pig.

Metabolite source	Host origin	Adhesion to mucus
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Buffer	-	100%
<i>L. fermentum</i>	Mouse	95%
30 <i>L. murinus</i>	Pig	36%
<i>Lactobacillus</i> sp. strain 152	Pig	48%

The products according to the invention consist of 35 metabolites including high molecular weight proteinaceous compounds produced by strains of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to

which the products will be administered.

In a preferred embodiment the strains of lactobacillus is *Lactobacillus crispatus* (fermentum).

Both low and high molecular weight compounds are

- 5 inhibitory to pathogens. However, the preferred products are high molecular weight, proteinaceous metabolites produced by strains of *Lactobacillus crispatus* (fermentum), which metabolites have the following characteristics:
 - a) they have molecular weights greater than 8,000;
 - 10 b) they are heat sensitive;
 - c) they are sensitive to acid buffers;
 - d) they bind to enteropathogenic *E. coli* strains;
 - e) they have enhanced activity in the presence of lactic acid;
- 15 f) the production of which is favoured by growth in complex media rather than in semi-defined medium;
- g) the production of which is favoured in semi-anaerobic growth conditions;
- h) the production of which is optimal in the late log
- 20 phase and the stationary phase of growth of the lactobacilli;
- i) they are released into the growth medium.

As is stated above, it is known that primary metabolites of *Lactobacillus*, especially *L. acidofilus*, is inhibitory to the growth of pathogens, but it is totally new that also high molecular weight products are effective in this aspect. Also it is very surprising that the metabolites, both low and high molecular weight compounds, also inhibit the adhesion and survival of pathogens.

30 An optimal method of producing the products according to the invention is also provided. In this method a strain of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to which the products will be administered is cultured in complex media under semi-anaerobic growth conditions, whereby the optimal production of metabolites occurs in the late log phase and in the stationary phase of the growth, and the metabolites are

recovered from the growth medium into which they are released during the culturing.

The preparations according to the invention can either comprise the metabolites defined above or viable 5 strains of the *Lactobacillus* that have the capacity of producing the defined metabolites. In any cases, the preparations may comprise pharmaceutically acceptable constituents. The administration of viable cells will allow production of metabolites *in vivo*, without 10 colonization being achieved or required.

The preparations according to the invention are administered to animals including, for instance, humans, piglets and chicken. The dosage could well be estimated by the person skilled in the art of human or veterinary 15 medicine.

Strain selection for dietary adjuncts

Many of the early studies concentrated on the beneficial effect of ingesting *lactobacilli* fermented milk products and *lactobacilli* strains used in the food 20 industry. More recently, attention has been directed towards specifically selecting *lactobacilli* strains of gastrointestinal origin and with desirable characteristics (e.g. reviewed by Klaenhammer, 1982). This concept has already been extended to using host specific *lactobacilli* 25 for producing a fermented milk product (Cole and Fuller, 1984; Ratcliffe et al, 1986).

Our first step in developing a *lactobacillus* preparation that can induce a beneficial effect, has been to define the target that is an antagonistic action against 30 pathogens, and then develop a rapid screen to ensure that the *lactobacilli* to be used has this characteristic. In addition, it is confirmed that the selected strain has the capacity to remain viable and active in the digestive tract. The survival of *lactobacilli* cells in human stomach 35 acidity and during transit through the tract has been investigated both *in vivo* and *in vitro* (Robins-Browne and Levine, 1981; Lindwall and Fonden, 1984; Pettersson et al, 1983a, 1983b; Lindwall and Fonden, 1984; Conway et al,

1987) and our strains have been selected with enhanced survival capacity.

Stability of desired characteristics

Many of the earlier preparations were not consistent 5 with regards to the viability of the preparation, as experienced by Clements et al (1983). These workers used different batches of the same commercial bacterial preparation and obtained conflicting results in human study.

10 There have been numerous examples of instability of specific character traits. Once a strain with the desired characteristics is selected, the stability of viability and various characteristics should be investigated because there have been numerous examples of instability of specific character traits. Instability will obviously lead to 15 inconsistencies in results e.g. failure to observe antagonistic effects. We have observed a loss of the capacity to produce a high molecular weight bacteriocin-like compound from some gastrointestinal isolates while other 20 strains of ours exhibit extremely stable antagonistic properties.

Lactobacilli strains isolated from the porcine 25 gastric epithelium, including strains 152 and 104, exhibit an antagonistic effect on the growth of pathogenic *E. coli*. Strain 104 was administered to piglets in a field study and the results look very favourable as to the beneficial role that strain 104 has within the gastrointestinal tract.

30 In a similar study the human strain *L. fermentum* KLD3 was studied.

Within the gastrointestinal tract, the interactions 35 between lactobacilli and coliforms encompass more than just growth inhibition. We have also considered the effect of lactobacilli on the colonization potential of the coliforms.

Antagonistic effects of Lactobacillus spp. on E. coli colonization potential

We have studied the effects of lactobacillus metabolites on the capacity of E. coli K88 to adhere to

5 ileal mucosa because adhesion via the K88 fimbriae represents the first step in the infection process. A number of lactobacillus strains have been examined and it was noted that L. fermentum typical strains produced metabolites with molecular weights greater than 8,000

10 (because they do not pass-through dialysis tubing with that size cut-off) which inhibited the adhesion of the K88 fimbriae. The mode of action appears to be that the lactobacilli metabolites bind to the mucus and thereby inhibit adhesion. Further fractionation of the metabolites

15 showed that the active fraction has a molecular weight greater than 30,000 and that it is not the same compound which inhibits growth of the E. coli as presented below. The presence of the K88-adhesion-inhibitory substance was influenced by the nutrients supplied to the lactobacilli.

20 Antagonistic effect of Lactobacillus crispatus strain 104 on growth of E. coli

Lactobacillus crispatus strain 104 was found to inhibit the growth of E. coli strain C23. Inhibition was not only found with the crude supernatant but also with

25 dialysed supernatant, indicating a substance other than lactic acid, acetic acid or H_2O_2 as the antagonist. We have determined the optimal growth conditions for the production of this antagonistic product by strain 104, characterized the structure and function of the antagonist, and examined the range of bacteria which are

30 sensitive to this antagonistic product.

Characterization of L. crispatus strain 104 revealed that it consisted of two different colony variants, smooth and rough, when plated on agar plates. On MRS-agar plates

35 smooth colonies were exactly round and shiny, whereas the rough colonies were irregular in shape and dull.

To be able to find optimal conditions for the production of the antagonist by strain 104 rb, the influence of carbon source, oxygen tension, and growth phase were investigated. Glucose was the only carbon 5 source, out of 10 tested, that allowed the production of the antagonist. Although strain 104 rb grew well on saccharose, melibiose, maltose, and raffinose, no antagonistic activity could be detected in the supernatant of these cultures. Semi-anaerobic conditions, as present in 10 anaerobic jars with a lighted candle, favoured the production of the antagonist. In the supernatant of cultures, uncubated unshaken under aerobic conditions less activity was found, and no activity at all in the supernatant of anaerobic cultures. Strain 104 rb did not 15 grow in aerated (shaken) flasks. Test for antagonistic activity of supernatants from different growth phases of strain rb showed that most of the antagonist was produced in the stationary phase.

Parallel to these experiments the antagonistic 20 product of strain 104 rb was characterized. From the cut off of the dialysis membrane it was known that the molecular weight was higher than 8000. In further experiments it could be shown that the antagonistic product was heat sensitive and sensitive to acid buffers. When the dialysed 25 supernatant of strain 104 rb was pre-incubated with E. coli, re-centrifuged to remove the E. coli cells and then tested, no growth inhibition of E. coli was found. This indicated that the antagonist was binding to E. coli cells. All these characteristics make it plausible that 30 the antagonistic product of strain 104 rb is a protein.

In all the experiments mentioned above the antagonistic effect was measured as growth inhibition of E. coli. E. coli was inoculated in medium containing the 35 dialysed supernatant of strain 104 rb. By recording the growth of E. coli in comparison to a control, containing dialysed medium instead of supernatant, the inhibition of E. coli could be recorded. Since the antagonistic effect

16

was only small in these experiments, investigations were carried out, how the sensitivity of *E. coli* against the antagonist could be increased. *E. coli* was much more sensitive when the supernatant of strain 104 rb was added to stationary phase cells, together with the amount of lactic acid, acetic acid, and ethanol produced by strain 104 rb in BHI containing 2% glucose (Tab. 5). The antagonist significantly increased the effect of the acids and ethanol on *E. coli*. While 6.3×10^5 CFU of *E. coli* were found in the control after 12 hours of incubation, only 2.4×10^4 CFU were found in the cultures with added supernatant. The same results were obtained, when *E. coli* was cultivated for 12 hours in medium with 2% glucose before the supernatant of strain 104 rb was added (Tab. 6).

Table 5

Cell number of *E. coli* C 23 after 24 hours of incubation. Cultures were grown in BHI medium for 12 hours (stationary phase) before additions were made.

20	Addition	Cell number after 24 h
	Control	4.2×10^8
	Supernatant	4.6×10^8
25	Control + lactic acid + ethanol + acetic acid	6.3×10^5
	Supernatant + lactic acid + ethanol + acetic acid	2.4×10^4

Table 6

30 Cell number of *E. coli* C 23 after 24 hours of incubation. Cultures were grown in BHI medium with 2% glucose for 12 hours (stationary phase) before additions were made.

35	Addition	Cell number after 24 h
	Control	3.3×10^7
	Supernatant	1.1×10^5

Effect of Lactobacillus strain 104 on the growth of E. coli K88

E. coli K88 was grown under anaerobic conditions in BHI medium (brain heart infusion, Oxoid) with 2% glucose 5 in the presence and in the absence of Lactobacillus strain 104r or 104s.

In the cultures were Lactobacillus strain 104r or 104s were present, the growth rates of E. coli were reduced and the viability of E. coli K88 in the stationary 10 phase dramatically decreased (Fig. 1). While 6.3×10^8 cfu of E. coli K88 were found in the control culture after 24 h, less than 10 viable cells were present in the cultures with the lactobacilli.

To exclude effects of low molecular weight acids and 15 H_2O_2 produced by the lactobacilli, the supernatant was dialysed and then tested for effects on growth (B.) and viability (C.) of E. coli K88.

The results are shown in fig. 1.

Effect of dialysed supernatant on the growth of E. coli 20 K88

Dialysed supernatants of 28 h cultures of Lactobacillus train 104r or 104s, BHI + 2% glucose grown, were mixed 1:1 with anoxic BHI medium and inoculated with E. coli K88. Dialysed BHI medium was used as control. The pH 25 was adjusted to 6.0 in all experiments.

The growth of E. coli K88 was only slightly affected by supernatant of the smooth variant of strain 104, while the rough variant supernatant clearly reduced growth (Fig. 2a). The growth inhibition was enhanced 4-fold when the 30 supernatant of strain 104r was concentrated 10-fold by freeze drying (Fig. 2b).

The results are shown in fig. 2.

Effect of the dialysed supernatant on the viability of E. coli K88

35 E. coli K88 was pregrown to stationary phase in BHI with 2% glucose, before the addition of supernatant of Lactobacillus strain 104r or 104s. Dialysed BHI served as

control supernatant. The pH was adjusted to 5.0 in all experiments. After 24 h, the number of viable *E. coli* K88 cells was determined by plate counts.

5 About 1000 times less viable cells were found in the cultures where the supernatants of the lactobacilli were added as compared to the control (Table 6). The culture supernatant of the smooth variant had a stronger inhibitory effect than the rough variant.

Table 7

10 Cell numbers of *E. coli* K88, 24 h after the addition of the lactobacilli supernatants or dialysed BHI.

Values given are means of three independent measurements.

Addition	Cell number
15 dialysed BHI	1.9×10^7
supernatant of strain 104r	2.1×10^4
supernatant of strain 104s	1.0×10^4

Characteristics of a *Lactobacillus* spp antagonistic effect
20 against pathogenic *Escherichia coli*

The metabolites of *Lactobacillus* strain 104 of porcine gastrointestinal origin were examined for their inhibitory effect on the growth of a pathogenic *E. coli* K88 strain. Preliminary studies showed that the growth of 25 *E. coli* strain was inhibited not only by the crude culture supernatant but also after dialysis of the spent culture fluid, indicative of the presence of active components other than lactic acid and acetic acid or hydrogen peroxide. The culture of *Lactobacillus* strain 104 on agar plates yielded two different colony variants, smooth and rough. The rough strains showed an at least 10 times enhanced antagonistic activity against growth of *E. coli* K88 than the smooth strains. In addition the rough and smooth strains showed different adhesive capacities. For 30 the rough strain 104 rb, the stability in MRS, BHI or LDM broth was examined and the antagonistic metabolite characterized. In addition, the influence of the carbon 35

source, oxygen tension, and growth phase on the activity of the antagonist were investigated. It was found that *E. coli* growth was inhibited by a high molecular weight compound that was heat and acid sensitive. The antagonist

5 bound to *E. coli* cells and from the data it is plausible that this metabolite of strain 104 rb is proteinaceous.

Inhibition of adhesion of enterotoxigenic *Escherichia coli* K88 to pig ileal mucus by metabolites of *Lactobacillus crispatus* strain 104

10 The effect of metabolites of *L. crispatus* on adhesion of *E. coli* K88 to piglet ileal mucus was investigated. This was studied in an in vitro adhesion assay by pre-treating immobilized mucus with *Lactobacillus* metabolites. These were prepared from overnight culture supernatants of

15 *L. crispatus* by dialyzing and then fractionating through ultra filters with the cut off at the molecular weight of 10,000 and 30,000. It appears that there are metabolites produced when *L. crispatus* is grown in BHI or LDM broth, that adhere to the ileal mucus and thereby inhibit

20 adhesion of *E. coli* K88. The active fraction, which is partially destroyed by heating, has a molecular weight greater than 30,000. Treatment with periodate, however, reduced the antagonistic effect, suggesting that compound(s) with carbohydrate constituents are active in the

25 blocking of the receptor for the K88 fimbriae.

Optimal culture conditions for the production of the antagonistic product by *Lactobacillus* strain 104
Stability with subculturing

30 The antagonistic action of the supernatant against *E. coli* K88 remained unchanged after 100 transfers of the cultures in liquid BHI or MRS medium or repeated freezing of the cultures.

Medium composition

35 Complex media, such as BHI or MRS, favoured the production of the antagonistic product.

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Production was reduced in dialysed BHI medium or LDM medium (semi-defined). Glucose was the only carbon source, out of 10 tested in LDM medium, that allowed the production of the antagonist.

5 Oxygen tension

Semi-anaerobic growth conditions favoured the production of the antagonist. Less activity was found in the supernatant of cultures, incubated unshaken under aerobic conditions.

10 Nearly no activity was found in the supernatant of anaerobic cultures.

Growth phase

Most of the antagonist was produced in the stationary phase.

15 Characterization of the antagonistic product

1. Antagonistic effect not due to:

- bacteriophage

Dilution to extinction of the supernatant of the lactobacilli cultures gave no bacteriophage plaques.

20 - hydrogen peroxide or low molecular weight acids

The antagonistic effect was still present in dialysed supernatant.

- low pH

The pH in the controls and the cultures with added 25 supernatant was adjusted to the same value.

2. Properties of the antagonistic product

- > 10000 Dalton

The dialysed supernatant still contained the antagonistic activity.

30 - heat sensitive

Heating of the supernatant to 100,5°C for two minutes destroyed the antagonist.

- sensitive to acid buffers

After dialysing the supernatant against acid buffers 35 no antagonistic activity was detected.

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- not sensitive to pronase or trypsin

Addition of pronase or trypsin had no effect on the action of the antagonist against *E. coli* K88.

- binds to *E. coli* K88

5 When the supernatant of *Lactobacillus* strain 104r was pre-incubated with *E. coli* K88, re-centrifuged to remove the *E. coli* cells and then tested, no growth inhibition of *E. coli* was found.

10 These features make it plausible that the antagonist is a protein which is not sensitive to pronase and trypsin.

Antagonistic effects of *Lactobacillus fermentum* of human origin on pathogens

15 The results using method 101/1 are presented in Table 8 and from the data it can be concluded that *L. fermentum* strain KLD has a marked antagonistic action on all bacterial isolates tested.

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Table 8

Antagonistic action of *L. fermentum* KLD against a range of strains. All strains are human pathogens except *E. coli*

5 Sb5 and *Streptococcus faecium* which are indigenous to the mouse gastrointestinal tract. Results are expressed as the size of the zone inhibition of growth of the pathogen when overlaid on colonies of *L. fermentum* KLD after growth of the KLD strain in MRS broth.

10 Bacterial strain Zone of inhibition (mm)

	Campylobacter jejuni	12
	<i>E. coli</i> C21	7
	<i>E. coli</i> C22	7
15	<i>E. coli</i> H10407	7
	<i>E. coli</i> 334	8
	<i>E. coli</i> B2C	7
	<i>E. coli</i> -R	7
	<i>E. coli</i> KS219	7
20	<i>E. coli</i> Sb5	6
	<i>Salmonella</i> sofia	7
	" eq.ph	7
	<i>Streptococcus faecium</i>	6

Method 101/1 Screening for antagonistic metabolites

25 This screening method can be used for either actively growing *lactobacillus* cultures or for bacterial suspensions prepared from the freeze dried preparations. The latter suspensions were prepared by shaking 2 g of dried powder together with 18 ml PBS. A point inoculum (10 μ l) 30 of the overnight culture, or the bacterial suspension in PBS, was placed on an BHI + 2% glucose plate. Two such point inocula were tested per plate. After 48 h incubation at 37°C in a candle jar, the pathogen to be tested was overlaid on top of the *lactobacillus* colony. This overlay 35 consisted of 10 μ l of an overnight culture of the pathogen in 3 ml soft agar. The plates were incubated overnight and the growth inhibition measured by the size of the zone of

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no growth of the pathogen around the lactobacillus colony.
To compare from one plate and analysis to another, consistently uniform plates were prepared.

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31a

FIGURE LEGENDSFIG 1:

5 Viable cell number of *E. coli* K88 during growth in BHI + glucose with or without addition of lactobacilli.

Δ *E. coli* K88 alone

○ *E. coli* K88 and *Lactobacillus* strain 104r

● *E. coli* K88 and *Lactobacillus* strain 104s

FIG 2:

10 Growth of *E. coli* K88 in BHI (Δ) with addition of

15 a) supernatant of *Lactobacillus* strain 104r (○)

supernatant of *Lactobacillus* strain 104s (●)

b) 10-fold concentrated supernatant of strain 104r (□)

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CLAIMS

1. Products for inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or for inhibiting the growth and/or survival of pathogens in animals including humans, characterised in that they consist of metabolites including high molecular weight proteinaceous compounds produced by strains of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to which the products will be administered.
2. Products according to claim 1, characterised in that they are metabolites including high molecular weight proteinaceous compounds produced by *Lactobacillus crispatus* (fermentum) and related isolates.
3. Products according to claim 1, characterised in that they consist of high molecular weight proteinaceous metabolites produced by strains of *Lactobacillus crispatus* (fermentum) or related isolates, which metabolites have the following characteristics:
 - a) they have molecular weights greater than 8,000;
 - b) they are heat sensitive;
 - c) they are sensitive to acid buffers;
 - d) they bind to enteropathogenic *E. coli* strains;
 - e) they have enhanced activity in the presence of lactic acid;
 - f) the production of which is favoured by growth in complex media rather than in semi-defined medium;
 - g) the production of which is favoured under semi-anaerobic growth conditions;
 - h) the production of which is optimal in the late log phase and the stationary phase of growth of the lactobacilli;
 - i) they are released into the growth medium.

4. A method of producing products for inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or for inhibiting and/or survival of pathogens in animals including humans, which products are metabolites including high molecular weight, proteinaceous compounds produced by strains of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to which the products will be administered, *characterised* in that a strain of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to which the products will be administered is cultured in complex media under semi-anaerob growth conditions, whereby the optimal production of metabolites occurs in the late log phase and in the stationary phase of the growth, and the metabolites are recovered from the growth medium into which they are released during the culturing.

5. Preparations containing, as an active ingredient, metabolites including high molecular weight, proteinaceous compounds produced by strains of *Lactobacillus* preferably originating from the gastrointestinal tract of the animals to which the preparations will be administered, and, optionally, pharmaceutically acceptable constituents.

6. Preparations containing viable strains of *Lactobacillus* preferably originating from the gastrointestinal tract of the host to which the preparations will be administered, which strains have the capacity of producing metabolites including high molecular weight, proteinaceous compounds active in inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or inhibiting the growth and/or survival of pathogens in animals including humans, and, optionally, pharmaceutically acceptable constituents.

7. Preparations according to claim 5 or 6, *characterised* in that the strains are *Lactobacillus crispatus* (*fermentum*) or related isolates.

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8. Method of inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or inhibiting the growth and/or survival of pathogens in animals including humans, characterised in that metabolites 5 including high molecular weight, proteinaceous compounds produced by strains of *Lactobacillus*, preferably originating from the gastrointestinal tract of the animals including humans which are to be treated, are administered to the animals including humans.

10 9. Method of inhibiting the adhesion of pathogens to gastrointestinal epithelial mucosa, or inhibiting the growth and/or survival of pathogens in animals including humans, characterised in that viable strains 15 of *Lactobacillus*, preferably originating from the gastrointestinal tract of the animals which are to be treated, are administered to the animals, which strains have the capacity of producing metabolites including high molecular weight, proteinaceous compounds.

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FIG. 1

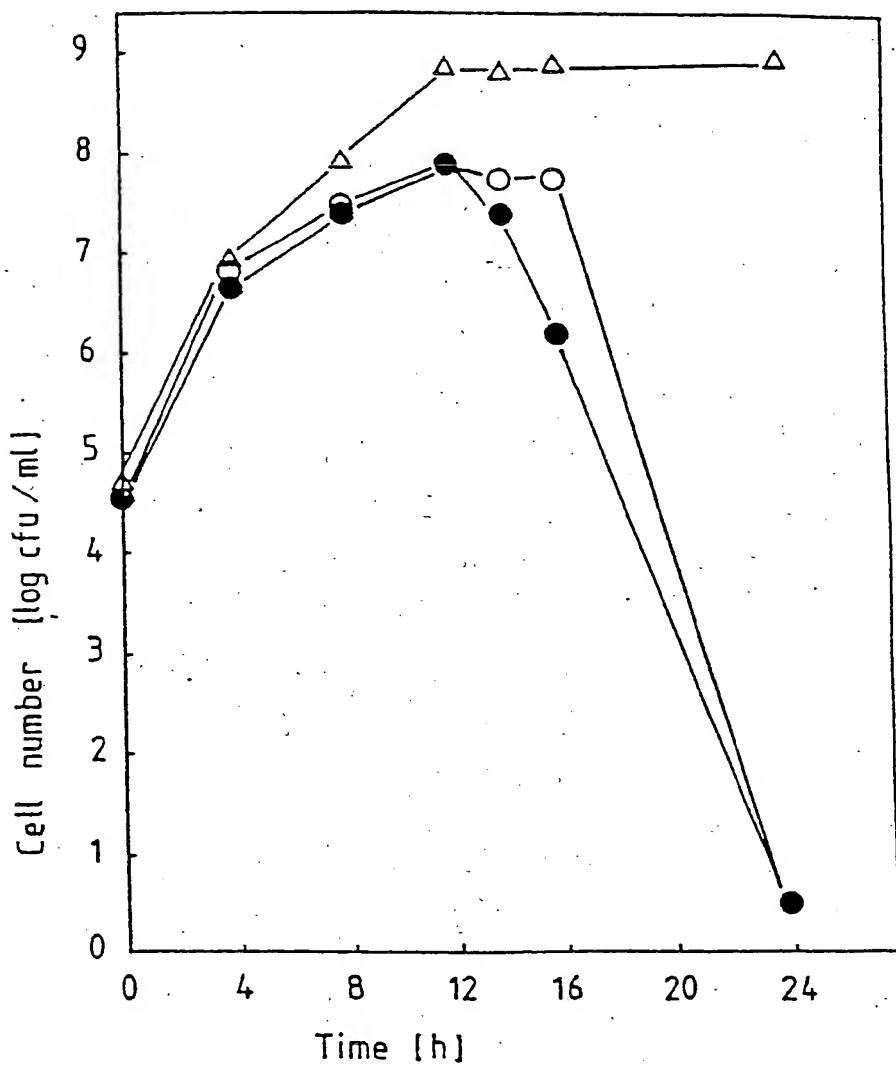
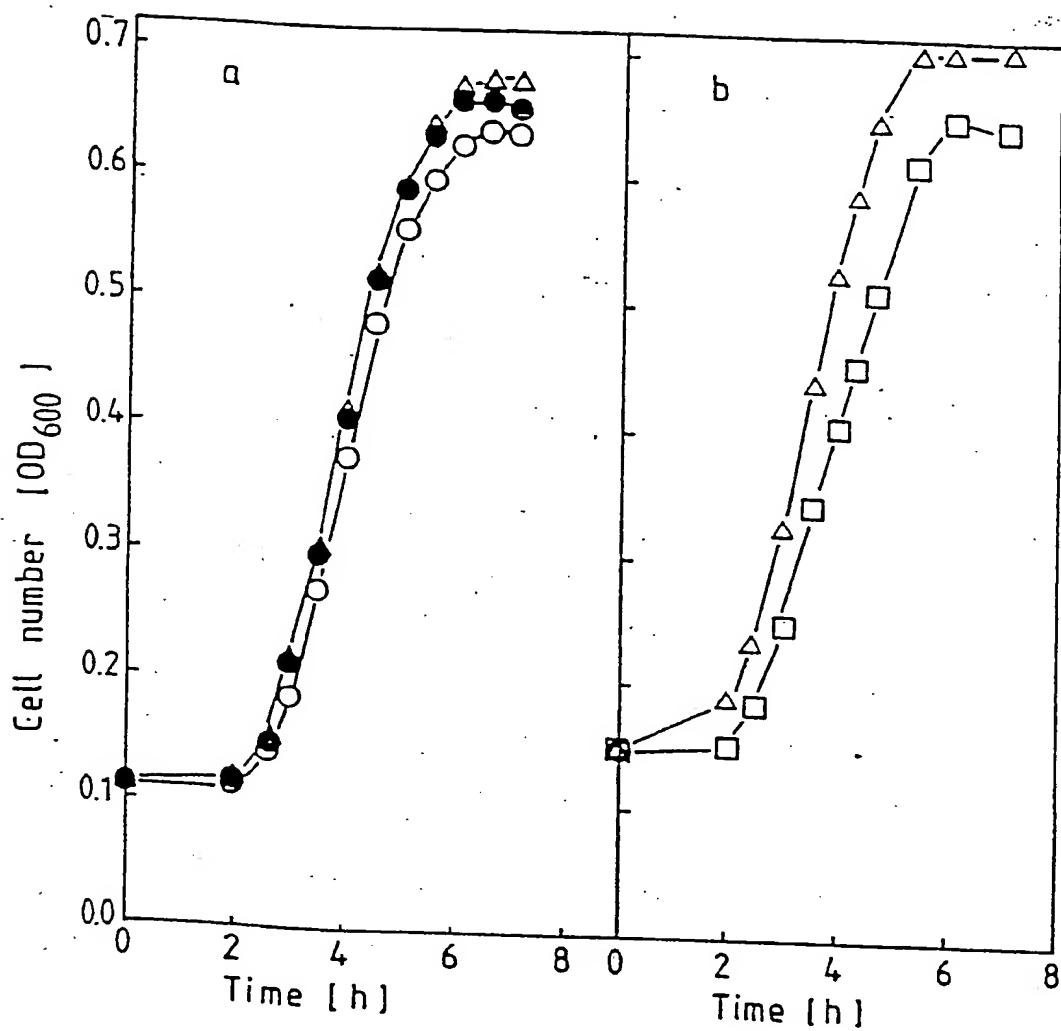
**SUBSTITUTE SHEET**

FIG. 2



SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 90/00105

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: C 07 K 15/04, C 12 P 21/00, A 61 K 35/74 // (C 12 P 21/00
C 12 R 1:225)

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
IPC5	A 61 K; C 07 K

**Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in Fields Searched⁸**

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	EP, A2, 0203586 (PIONEER HI-BRED INTERNATIONAL, P.O.) 3 December 1986, see especially page 5 lines 1-23 --	1,2,4-7
X	INFECTION AND IMMUNITY, Vol. 49, No. 3, 1985 Kazuoki Ishihara et al: "Growth Inhibition of Streptococcus mutans by Cellular Extracts of Human Intestinal Lactic Acid Bacteria ", see page 692 - page 694 --	1,2,4-7
X	US, A, 4767623 (CONWAY ET AL) 30 August 1988, see the whole document --	6
X	EP, A2, 0033584 (SCHNEITZ, CARITA ELISABETH) 12 August 1981, see especially claim 7 -----	6

* Special categories of cited documents: ¹⁰

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search 14th May 1990	Date of Mailing of this International Search Report 1990 -05- 17
International Searching Authority SWEDISH PATENT OFFICE	Signature of Authorized Officer Mikael G:son Bergstrand

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE¹

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. Claim numbers 8-9, because they relate to subject matter not required to be searched by this Authority, namely:

Methods for treatment of the human or animal body by therapy.

2. Claim numbers....., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claim numbers....., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING²

This International Searching Authority found multiple inventions in this international application as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims. It is covered by claim numbers:

4. As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 90/00105

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 90-05-07.
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date		Patent family member(s)	Publication date
EP-A2- 0203586	86-12-03		AU-D- 5791586 JP-A- 62089625	86-12-04 87-04-24
US-A- 4767623	88-08-30		AU-B- 589384 AU-D- 5097285 EP-A- 0201579 JP-T- 62500722 SE-A- 8405587 WO-A- 86/02837	89-10-12 86-06-03 86-11-20 87-03-26 86-05-09 86-05-22
EP-A2- 0033584	81-08-12		AT-E- 7201 CA-A- 1151066 US-A- 4689226	84-05-15 83-08-02 87-08-25

FIG. 1

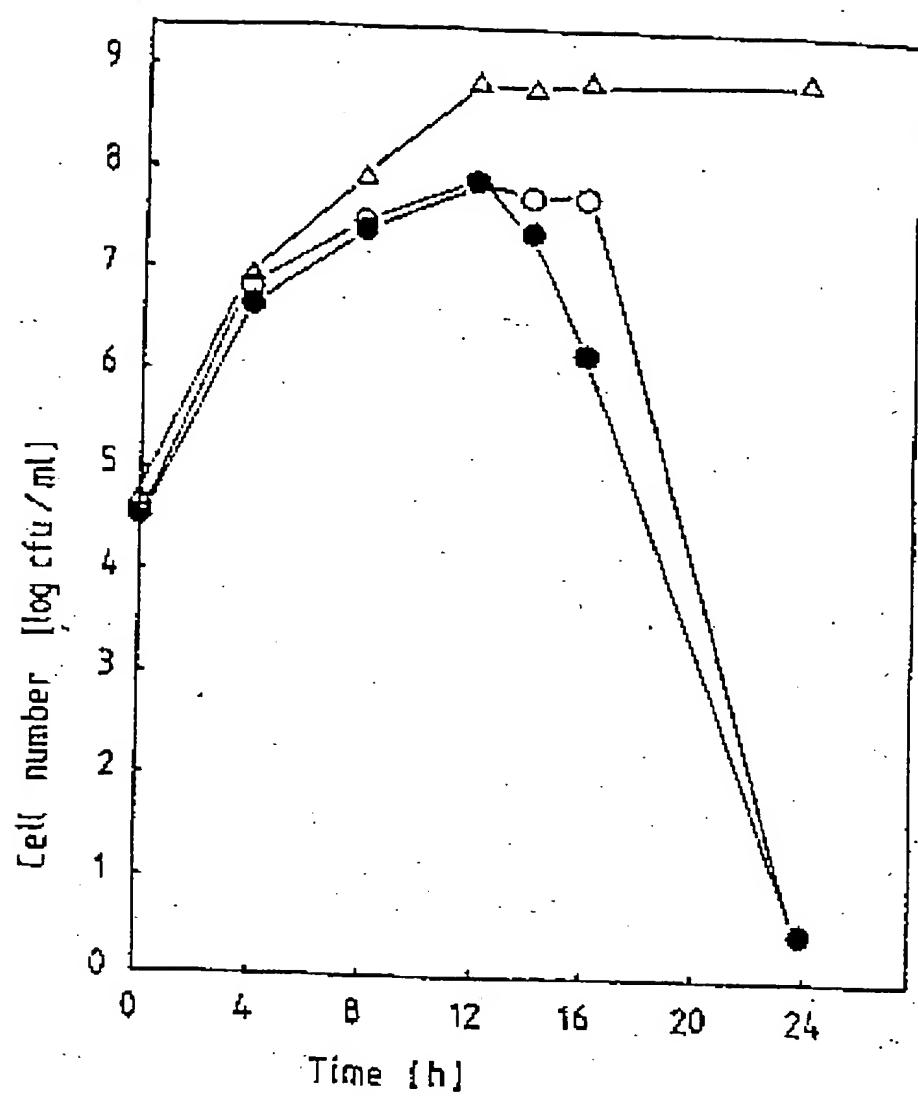
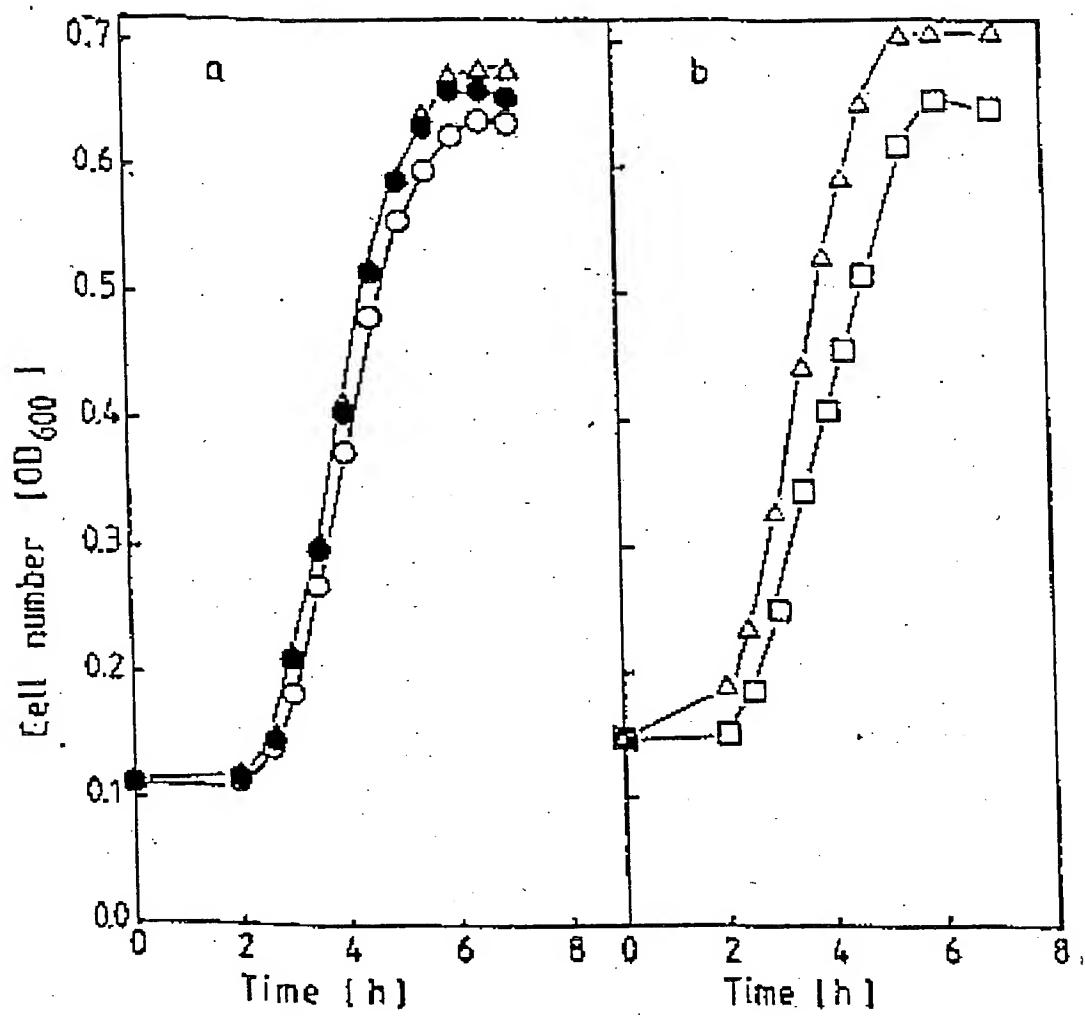
**SUBSTITUTE SHEET**

FIG. 2



SUBSTITUTE SHEET